

Multi-Window Web Browser with History Tree Visualization for Virtual Reality Environment

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ABSTRACT

This study introduces a multi-window web browser system to visualize all visited pages and their link structure in a virtual reality (VR) environment. Using VR space, it is possible to visualize many pages and their connections while maintaining their readability. To evaluate the usefulness of our system, we conducted a user study to compare our system to a conventional single-window browsing system. We then found that our system reduces the browsing operations and time for the task of comparing multiple web pages.

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1 BACKGROUND

The need for web browsers for virtual reality (VR) settings is growing as inexpensive Head-Mounted-Display (HMD) devices become more widely available. Unlike applications for two-dimensional (2D) monitors with limited display space, VR applications can present information in a vast three-dimensional (3D) space. Some VR browsers that utilize these benefits have been developed. For example, the Oculus Browser [4], which is a built-in browser for Oculus Quest permits one to open up to three windows once in a VR space. Also, VRrowser [8] supports the users to open multiple windows and arrange them in a virtual workspace. However, their primary concept is to provide numerous independent browsers in a VR environment, and they do not depict the interaction between pages, which may cause users to become confused.

Many researchers have established methods to visualize tree structures of websites to support exploring link structures and browsing histories. Some methods, such as WebMap [3], MozaicG [1], and Pad++ Web Browser [2], visualized tree structures in 2D space, whereas others, such as WebPath [5] and WWW3D [7] used 3D space. However, these methods represent each page with a primitive shape (circle or sphere) or a reduced thumbnail to visualize the link structure within 2D monitors with spatial limitations. It is



Figure 1: Overview of our system. Our system visualizes all visited web pages and their link structure in a VR space (a). The windows are aligned on a U-shaped curve (b). In the user study, the participants browse a property website (c).

difficult for the users to understand both the linked structure and detailed contents of web pages.

2 OUR METHOD

Our goal is to develop a web browser that supports the users to explore browsing history efficiently. For this purpose, we introduce a browser that visualizes all visited pages and their link structure in 3D VR space. It is feasible to display many pages while preserving their readability thanks to the use of a vast VR space. With visualization of link structure, the users can understand the relationship between pages quickly.

Figure 1a is a screenshot of our system. It presents multiple web pages in separate windows in a VR space. Our system opens the linked website as a new window on the right side of the visited page when the user points and clicks a link on a page with a VR controller. Clicking multiple links on one page will open multiple windows arranged vertically. Our system visualizes the link structure by connecting a window and its parent with a white edge.

After visiting multiple web pages, our system presents multiple windows to the user. The page that has the attention of the user should be displayed largely. On the other hand, pages that are far from the focused page should only present draft information. Our system then arranges all windows along a U-shaped curve around

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the user as in Figure 1b. With this arrangement, the windows in front of the user appear larger, while those further away appear smaller. The user can scroll the arranged windows horizontally and vertically by tilting a stick on the VR controller (see supporting video for detail). The user can also close a window by clicking its close button.

3 USER STUDY

3.1 Tasks

We conducted a user study to evaluate the usefulness of our system. Specifically, we compared two browsing methods, such as a conventional single-window browsing and our multi-window browsing in a VR space. Only one window is displayed in the single-window browsing, and the users browse web pages by using links and back/forward buttons.

Each participant performs the following tasks twice using the two browsing methods. We balanced the order of the two methods among the participants. First, participants get instructions on a browsing method. Next, they perform practice tasks; they browse a property website that we designed for this study and are asked six questions about the website (Figure 1c). Participants freely explore the website to find the answer for each question. The system displays a question and its options on a panel above the non-dominant hand. Participants select an option to answer. Next, the participants perform evaluation tasks; they browse a property website with different parameters and answer nine questions. After answering all the questions, participants remove HMD and perform workload evaluation using NASA-TLX [6]. Participants are asked questions on the overall experience at the end of the experiment.

The property website used in this study consists of seven pages categorized into three layers: (1) a list item page containing links to three rental property pages, (2) three rental property pages containing their overviews and links to information pages, and (3) information pages containing detailed information (room size, building age, number of rooms, floor, access, and the room facing). During the tasks, we asked two types of questions. The first is a simple question where a participant can obtain an answer from a page. Such as "Q. How many rooms are there in Saison Toyosu? A. 2 Rooms / 3 Rooms / 4 Rooms". Second is a complex question where a participant has to compare three pages. Such as "Q. Which property is the latest in age? A. Saison Toyosu / Lark Toyosu / Court Toyosu". In nine questions asked during the task, questions 0, 1, 3, 5, and 7 are simple questions, and questions 2, 4, 6, and 8 are complex questions. Since a participant performs the tasks using two browsing methods, we designed two property sites and questions with varying parameters.

3.2 Results and Discussion

Seven students, ranging from 21 to 23 in age, participated in the study. Most of them utilize web browsers on PCs and smartphones daily, and all but one had little experience with VR. We measured the number of browsing operations and time to answer each question. The browsing operation includes clicking links and pressing back/forward buttons. We excluded three question-answer cases as outliers; two cases were wrong answers, and one case took more

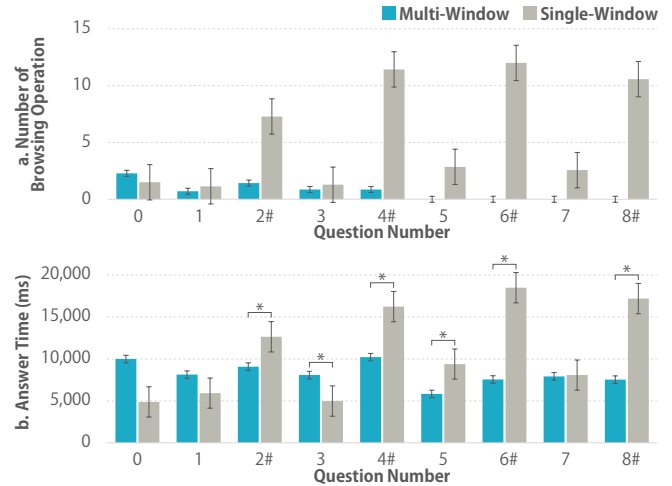


Figure 2: The user study results: the number of browsing operations (a) and time (b) to answer each question. Questions 0, 1, 3, 5, and 7 are simple questions, and questions 2, 4, 6, and 8 are complex questions. "*" represents a significant difference confirmed with a paired t-test.

than 70 seconds to answer owing to a lack of understanding of the operation. The three cases occurred in the single-window browsing.

Figure 2a summarizes the mean number of browsing operations for each question. With attention to the complex questions (Question 2, 4, 6, and 8), the mean number of operations was 10.19 with the single-window browsing and 0.57 with our multi-window browsing. This result indicates that our system permits participants to browse the property site with much fewer operations. The number of browsing operations was zero with our multi-window browsing especially after question 4. This means that the users opened all pages until question 4, and they just compared pages arranged in a tree structure. On the other hand, the user has to perform browsing operations for all questions in the single-window browsing.

Figure 2b shows the mean time taken for answering each question. For all complex questions, the time taken with the multi-window browsing was significantly shorter than that with the single-window browsing ($p < 0.05$), indicating that our system supports the user to compare multiple pages efficiently. Among the simple questions, questions 3 and 5 showed a significant difference between the methods ($p < 0.05$). Especially in question 3, multi-window browsing takes a long time. We think this is because question 3 requires the users to open new pages, and opening a new page in the multi-window browsing creates gaze movement overhead.

We also measured the subjective workload of each method with the NASA-TLX. Participants rated the six subscales within 100-points and compared the importance of each subscale pairwise. The subscales include mental demand, physical demand, temporal demand, overall performance, effort, and frustration level. We calculated the weighted mean of six subscales as the weighted workload (WWL) score. The WWL score was 31.61 for the multi-window browsing and 51.52 for the single-window browsing, indicating that the workload with our multi-window browsing was significantly lower than that with the single-window browsing ($p < 0.05$).

4 CONCLUSION

This study proposes a multi-window web browser system that visualizes all visited pages and their link structure in a 3D VR space. A user study was conducted to compare our system with a conventional single-window browser. As a result, we found that our system reduced browsing operations and time in the task of comparing multiple web pages. Furthermore, we found that our system was superior in terms of the subjective workload from the evaluation using NASA-TLX. Our most important future task will be to assess the utility of our system when browsing a much larger website.

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